The Use of Pattern-Communication Tools and Team Pattern Recognition [1]

Abstract

This study extends the theory of Recognition Primed Decision-Making by applying it to groups. An experiment was conducted in which teams made resource allocation decisions while physically dispersed and supported with a shared virtual work surface (What You See Is What I See - WYSIWIS). The task required teams to recognize patterns and collaborate to allocate their resources appropriately. The experiment explored the use of tools (item vs. chunk level communication) designed to minimize the cognitive effort required to recognize and communicate patterns among team members. Dependent measures included pattern communication correctness, pattern communication time, resource allocation time, and outcome quality. All teams received significant financial rewards in direct proportion to their outcome quality. Teams supported with the pattern-communicating tools had significantly higher outcome quality and significantly less resource movements and allocation time than teams in the control condition. Further, the teams that used the chunk-communicating tool performed significantly better than the teams supported with an item-communicating tool.

Keywords
Collaboration, Communication, Pattern Recognition, Stimulating Structures, Transactive Memory

1. INTRODUCTION

Many decision environments are especially taxing to our limited cognitive resources of memory, attention and perception, and the extent to which these resources are available directly impacts task performance (Wickens, 1984). The importance of reducing cognitive effort stems from the notion that humans have limited cognitive resources. Multiple resource theory proposes that there are separate and finite reservoirs of cognitive resource (Wickens, 1984; 2002), some of which are potentially available simultaneously for different purposes. The capacity or resource models (e.g., Kahneman, 1973; Navon & Gopher, 1979; Wickens, 1984) view the human system

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as having a limited reservoir of resources that can be shared between tasks. Specifically, multiple resource theory is often used to understand and predict performance of multiple tasks. The concept of multiple resources refers to the underlying commodity, of limited availability, that enables task performance and which can support the relatively independent processing of different task components. Wickens (2002) describes how a concurrent task demand can result in interference or alternatively, can leave residual resources, or spare capacity, which can be applied to other tasks. To the extent that the cognitive effort to perform some task can be reduced, then people will be likely to make fewer errors, and to have more residual resources available for other task-related activities; in our case, group oriented tasks.

To illustrate this point, in Figure 1 we show a diagram of the Model Human Processor proposed by Card, Moran, and Newell (1986). The model shows various cognitive resources, including different types of memory (long-term and separate working memory stores for visual and auditory working memory), separate processors for perception, motor control, and an executive "cognitive" processor. Working memory refers to temporary or "short-term" memory that humans use to buffer our recent perceptions, or to gather our recollections from "long-term" memory.

Place Figure 1 About Here

Figure 1. Model of the Human Information Processor from Card, Moran, and Newell, (1986).

It requires some cognitive effort to retrieve memories from long-term storage. Once those long-term memories are "active" in short-term memory, it also takes some ongoing effort to keep them active. These efforts are expended by the cognitive processor, and are generally referred to as "attention." Humans have a finite amount of attention resource, which can be consciously directed to a variety of tasks, such as retrieving memories from long-term storage, maintaining memories in short-term storage, directing sensory activities (e.g. looking or listening carefully), and controlling motor processes. We have difficulty dividing attention among several tasks, or attending to all the information provided by the senses (Broadbent, 1958; Treisman 1969). As a result, we often do not perceive most of the information that is available to us (Lavie, 1995). As Nobel Laureate Herb Simon has said, "a wealth of information creates a poverty of attention (Varian, 1995, pp. 200)." The "perceptual" and "motor" processors also have limitations, i.e., the eyes and ears can detect a limited range of light and sound.

Short-term memory is limited to two independent stores of relatively small capacity (see Figure 1). The presence of separate memory stores has received significant recent support (Baddeley, 1992, 1998; Baddeley, Chincotta & Adlam, 2001; Wickens, 2002; Wickens & Liu, 1988; Winn, 1990). Baddeley's (1992) terminology has been generally adopted as the standard; he refers to these separate resources as "visual-spatial" and "articulatory-loop" memory. The notion of a "loop" refers to a strategy whereby we can keep items active in short-term memory through repeated sub-vocalizations. While Chase and Simon (1973a, 1973b) adopted Miller's (1956) estimate for the size of each short-term memory store as about 7 ± 2 items, more recently, the size of the visual-spatial store has been estimated as a maximum of 4 items (Zhang and Simon, 1985; Gobet and Clarkson, 2004; Gobet and Simon, 2000). These limitations are additive; it is possible to simultaneously hold about 4 items in visual-spatial memory while holding approximately 7 items in articulatory-loop memory.

To address some of these limitations, decision support tools have been developed to support individual cognition and these tools are successful because they strengthen specific cognitive strategies (i.e. "feature matching" Kaempf, Klein, & Wolf, 1996). In addition, performance increases when there is a good cognitive fit between the task and the data representation format (Dunn & Grabski, 2001; Vessey, 1991). While these tools are applicable to individuals, Keltner (1989) found that teams, rather than individuals, make many decisions. He observed that most important economic, political, legal, scientific, cultural, and military decisions are made by groups. Thus, considerable effort has been devoted to the development of groupware to support these domains (DeSanctis & Gallupe, 1987; Jessup & Valacich, 1993; McGrath & Hollingshead, 1994; Nunamaker, 1997).

Many studies have shown that groupware supported distributed (or virtual) teams can outperform face-to-face teams (e.g., Schmidt, Montoya-Weiss & Massey, 2001). However, within the large body of literature on groupware, we are not aware of any groupware that is specifically designed to optimize the utilization of human *cognitive* resources in group decision situations; most systems have addressed *behavioral* issues associated with human interaction. In this paper we address this shortcoming by proposing and testing a model of group cognition for collaboration drawn from the literature on individual cognition. Our research objective is to examine whether communication tools that are closely aligned with our cognitive structures lead to improved collaboration performance. Specifically, we will explore team pattern-recognition in a visual-spatial environment.

In our study, the choice to restrict modes of communication is deliberate. Baddeley's (1992; 1998) studies of working memory suggest that there are at least two independent channels of working memory: one for visual-spatial information, and another for articulatory-loop information. Since we are attempting to study fairly subtle influences of cognitive representation on group pattern-recognition, we seek to avoid confounding the results by isolating all communications to a single channel of working memory - the visual-spatial channel. This design has an additional advantage in that it emulates Simon and Gobet's (1998; 2000) seminal work on visual pattern-recognition in the domain of chess.

2. PRIOR RESEARCH

As discussed earlier, the human cognitive system has acute information processing limitations, one such being a short-term memory (STM) capacity of about seven items. To overcome this limitation, it has been theorized and shown that experts create a cognitive structure called a "chunk", where many related pieces of data are aggregated (Chase & Simon, 1973a, 1973b). The use of these cognitive structures is vital for encoding domain knowledge, pattern-recognition of situations and selective search techniques such as those used by chess experts.

Studies have demonstrated the advantages of chunking by studying the performance of skilled chess players who are able to encode and accurately recall unfamiliar chess positions shown to them for only a few seconds (Chase & Simon, 1973b; Gobet & Simon, 1996a). Interestingly, these same chess players were unable to accurately recall pieces randomly distributed on the board in no known pattern. To account for this discrepancy, Chase and Simon proposed that chess players stored chunks in long-term memory (LTM) corresponding to patterns of the pieces. When presented with material from their domain of expertise, Gobet (1997) showed that experts recognize patterns and place a pointer to these memory chunks in short-term memory (STM). These chunks, each of which contains several elements that novices see as units, allow experts to recall information well beyond what non-experts can recall.

Acquiring, communicating and processing information are critical activities for decision-making in a group setting. Ideally, groups should be less affected by the cognitive limitations of their members. Consider a team attempting to recall the names of all the US state capitals. It is likely that there will be several capitals that every member knows. This is information that the group holds in common. One would also expect that the gaps in the members' knowledge would complement each other to some extent, so that the collective recollection of the group would be superior to the average individual recollection.

In order to achieve the benefits of collective recall, the individual group members will require a system for encoding, storing, retrieving, and communicating. This system has been called a transactive memory system (Wegner, 1987). This system includes the cognitive abilities of the individuals as well as meta-memory, that is, the beliefs that the members have about their memories. Thus, the members of a group have access to the collective memory by virtue of knowing which person remembers which information. Under certain circumstances group memory has been shown to be superior to individual memory (Hinsz, 1990) and can lead to superior task performance (Moreland, 1999). More typically, however, the performance of a group rarely exceeds the performance of the group's best individual member (Hill, 1982). Ineffectiveness in transactive memory systems may be a result of inefficient communicating of information within groups. Research has shown that during collective recall, groups are more likely to exchange and discuss "common" information shared by all group members than information known by only one group member (Dennis, 1996; Wittenbaum & Stasser, 1996).

Just as transactive memory systems are dependent upon the existence of meta-memory, shared mental models require that group members maintain a meta-model of "who does what, when." Hutchins' (1991, 1995) work on distributed cognition suggests one mechanism to accomplish this goal by defining the unit of cognitive analysis as a distributed socio-technical system. The cognitive properties of this system are produced by an interaction between the structures internal to individuals and structures external to individuals. In particular, that portion of cognition that governs the coordination of the elements of a task might be represented in the external environment, and be available for inspection. By making this representation "public", the group can share it, using it to coordinate their activities.

This strategy has the potential to dramatically reduce cognitive effort associated with coordinating activities. For example, social insects use a strategy called "stigmergy" (Grassé, 1959) to cooperate. Stigmergy refers to a class of mechanisms, or public "stimulating structures", that mediate animal-animal interactions. The concept has been used to explain the emergence, regulation, and control of collective activities of social insects (Susi and Ziemke, 2001). Social insects exhibit a coordination paradox: they seem to be cooperating in an organized way. However, when looking at any individual insect, they appear to be working independently as though they are not involved in any collective task (Susi & Ziemke, 2001). The explanation of the seeming paradox provided by stigmergy is that the insects interact indirectly by placing stimulating structures in their environments. These stimulating structures direct and trigger specific actions in other individuals (Theraulaz & Bonabeau, 1999). Using this strategy, social insects having very little cognitive capacity are able to coordinate their activities and perform complex tasks. We believe humans can apply the same strategy with similar results. For example, Hutchins (1995) describes how a "heading bug" (what we would call a stimulating structure) placed in an airplane cockpit environment transformed a complex computational task into a simple perceptual task. The resulting reduction in cognitive effort was associated with a significant improvement in task performance. In the domain of information systems, stimulating structures would take the form of software artifacts.

In summary, group work places additional loads on the already limited memory resources of its members. To be effective, groups must dedicate some of their cognitive resources to transactive memory. It should be possible to improve group performance by reducing the cognitive effort required to maintain transactive memories. One way to reduce cognitive effort associated with coordinating activities in a group is to place stimulating structures into the public environment; by doing so one can convert effortful computational tasks into relatively effortless perceptual tasks.

Next, we present our model, Team Recognition Primed Decision Making (see Figure 2), which captures how stimulating structures can be utilized to compensate for cognitive limitations in a group decision-making situation (adapted from Klein's (1993) model of individual decision-makers). Klein's model emphasizes situation assessment through pattern recognition. Extending this concept to teams, we suggest that teams perform essentially the same steps as individuals; they assess the situation and perform "feature-matching" tasks which trigger recall of similar situations or patterns from their memory ("Situation Assessment" box in Figure 2). Our model then hypothesizes that teams communicate these situation assessments (patterns) among themselves (the "Pattern Communication" box). Next, teams select a response by adapting a strategy from their previous experience. Finally, teams execute their plan, and observe the results. This model has a feedback loop, whereby teams examine the effect of their actions and re-evaluate the ensuing situation for patterns and further action. We believe that stimulating structures can be most effective at triggering recall of templates during the situation assessment and pattern communication phases.

Place Figure 2 About Here

Figure 2: Team Recognition Primed Decision Making,
adapted from Hayne, Smith, and Turk (2002).

Kaempf, Klein, & Wolf (1996) found that individual experts spent most of their time scanning the environment and developing their situation assessments while relatively little time was spent selecting and implementing responses. If the situation assessment task has the same relative importance for teams as for individuals, then the initial focus for team decision support should be directed towards the development of tools to support collective situation assessment. Thus, our first hypothesis is:

H1: The outcome quality of the teams supported with a stimulating structure for communicating recognized patterns will be greater than the outcome quality of the teams without.

While we believe a chunk representation is the most appropriate stimulating structure for collective pattern recognition and communication, it is possible that any portion of the recognized pattern might be a suitable stimulating structure. Therefore, we designed our experiment to compare chunk representations with item representations within the pattern. As described earlier, a chunk is an aggregation of several individual data items.

The cognitive effort required to accomplish a task may not always be available to teams operating in naturalistic situations, so if a stimulating structure (i.e., software artifact) that maps to a cognitive chunk is placed in the external environment, its placement should not diminish the limited memory resources of the team. Interpretation of stimulating structures is primarily a perceptual task; such tasks require less cognitive effort than reasoning or computational tasks. Furthermore, these pointers enable the chunks to be accessed very swiftly.

Vessey (1991) coined the term "cognitive fit" to describe enhanced performance when there is a good match between the information emphasized in the representation type and that required by the task type. Similarly, we suggest that effectiveness and efficiency of the decision process will increase when there is a good "fit" between cognitive memory structures and the software artifact.

H2: Among teams supported with a stimulating structure for communicating recognized patterns, the communication correctness will be greater for teams *using a "chunk" level communication tool than for teams using an item communication tool.*

H3: Among teams supported with a stimulating structure for communicating recognized patterns, the communication time will be less for teams using a "chunk" level communication tool than for teams using an item communication tool.

H4a: The resource allocation time of the teams supported with a stimulating structure for communicating recognized patterns will be less than the resource allocation time of the teams without.

H4b: Among teams supported with a stimulating structure for communicating recognized patterns, the resource allocation time will be less for teams using a "chunk" level communication tool than for teams using an item communication tool.

3. METHOD

To test our hypotheses, we created a cooperative decision task that involves elements of pattern recognition and response selection. We built a shared visual surface (software) and a "thin" tool for pattern communication. To reduce the scope of our inquiry, we made some assumptions concerning the nature of the teams we wished to study. For example, we assumed that the members of our teams were drawn from an established organizational culture and that they shared a common body of knowledge with respect to the task domain (e.g., military personnel). We assumed that each team member understood his/her role, and the roles of the other members. We also assumed that the members were motivated to achieve the stated objectives.

For this study, we used 57 3-person teams of undergraduate students enrolled in a junior level course at a state university in the western United States. The data collection sessions took place in a large computer lab equipped with 40 workstations. Participant seating locations were randomly assigned so as to physically separate team members as much as possible. A maximum of two hours was available for each data collection session. Except for one, all teams finished well within the allotted time.

3.1 Decision Task and Experimental Procedure

Our collaborative game consisted of a java applet client incorporating a pattern-communicating tool and real-time play. The game was an extension of McGunnigle, Hughes & Lucas' (2000) two-player game to teams of three players playing independent decision scenarios or trials. The game was played against a computer opponent (not another team) on a shared computerized board (relaxed WYSIWIS; Hayne & Pendergast, 1995) consisting of 3 large circles with the intersecting areas representing "regions" (see Figure 3).

Place Figure 3 About Here

The objective of the game was for a team to win as many regions as possible in each trial. A win was scored for a region if the sum of the values of the played tokens for that region was greater than or equal to the "enemy" resources in that region. Each of the 3 resource patterns was constructed in a way that the participants could win all 7 regions if they placed their tokens appropriately. Thus, the scores could range from 0 to 7 on each trial (although scores less than 4 required a deliberate error, such as the players neglecting to place their tokens.) In pilot testing, we determined that the task of recognizing partially revealed patterns is sufficiently difficult to provide a significant test of team performance.

Three patterns were defined (see Figure 4 for the pattern set). Each pattern was a unique representation of the strength of the enemy's forces (ranging in value from 1 to 20) in each of the seven regions. We labeled the patterns as pattern "9" (because there was a 9 in the pattern), "10" (because there was a 10 in the pattern), and "14" (because there was a 14 in the middle of the pattern). These labels were chosen because the "9", "10" and "14" were distinguishing features of each of the patterns (while there was a "14" in the other patterns, in pattern "14" it was in the center).

The labels (chunk representations) were used in the "chunk" condition, but not in the "item" condition (described more fully below). By changing the rotational orientation (i.e., turned 120º) for each basic pattern, we generated 9 distinct variations. From this pool, we randomly drew the order in which the patterns would be presented for a session. Every team in our treatments viewed the patterns in the same ordering.

Place Figure 4 About Here

Depending on how much information was revealed about each pattern, we created a "definitive" scenario (enough information was revealed that the team "should" know what pattern they were facing). For instance, the 20, 19, 9 and one of the 1s was revealed during the trial shown in Figure 3 - this was sufficient to identify where the 14 was (Pattern 9). If less information was revealed, i.e. the pattern in Figure 3 did not include the 9, the team faced an "equivocal" pattern; it could be two of the three (Patterns 9 or 10). And, if even less information was revealed, i.e. the pattern in Figure 3 did not include the 9, 19 or the 1, the team faced an "uncertain" pattern in that it could be any of the three. Each team member saw the same information on the shared surface.

Each team member was given 7 resource tokens (lined up at the “dock” in Figure 3), valued from 1 to 7 and was randomly assigned a color (gray, green or yellow). Each region had 3 positions where tokens could be played (the small open circles). Tokens could be played by any combination of players within each region. In other words, a single player could play 3 of their tokens within the region, or each team member could play 1 token within the region (or any other combination). Only one token could be played in any particular position. Participants saw each other’s tokens being played in real-time. Players could not move another player’s tokens but they could “bump” (replace) a teammate’s token from a position by playing his/her own token in the same location. The bumped token went back to the player’s dock for potential replay.

In summary, a team had to combine its resources to overcome the “enemy” resource in each of the seven regions. For example, in Figure 3, a team is facing pattern “9”. In order to “win” the regions where the information is “revealed”, the team would have to play:

1. two “7”s and a “6” token in the three playing positions around the “20”,
2. the remaining two “6”s and a “7” token (that the team has available to play) in the three playing positions around the “19”,
3. some combination of tokens totaling 9 or greater (e.g., a 2, 3, and 4) in the region surrounding the “9” and,
4. any token at all in the region around the “1” in the center of the board (since any token will tie or be greater than the “1”).

To win the “unrevealed” regions, the team must now remember where the “14” is! While they can scatter their remaining tokens and win the regions with the “1”s, they must play at least 14 or greater where the “14” lies, to win that region (e.g., all three “5”s or two “5”s and a “4”). The teams were given significant incentive to win as many regions as possible (described below).

At the start of each trial, a randomly chosen pattern was partially revealed to the team members. Depending on the treatment, each team member could choose to communicate pattern information. Then, when a team member pressed the "Next" button (located at the bottom of Figure 3), they independently started the token movement phase of the trial. When all team members from one team were finished playing their tokens, they must press the "Next" button again and wait for the other team members to finish before they can start a new trial. Each team must play each trial in lock-step, i.e. individual team members may not get ahead of their team on trials because this game was meant to be played collectively, not as a nominal group. Finally, teams were not allowed to communicate in any way – they interacted through the pattern-communicating tool and/or the placement of their tokens.

All subjects received scripted training in the patterns (appropriate to the treatment) and in the use of the system immediately prior to the game. During 6 initial practice sessions, the subjects were shown the results of their decisions, and informed of the payoff that they would have received if the practice scenarios had been real. After the practice sessions, subjects were given one more opportunity to ask questions about experimental procedures. Following that, they participated in 24 paid experiment trials. At the completion of the last trial, the subjects filled out a survey, were debriefed, paid, and dismissed.

3.2 Manipulation

Our study included three treatments – baseline (BL), item level communication (IC), and chunk level communication (CC). In the BL treatment, team members were not provided with a tool for pattern communication. Therefore, they played the game by moving their tokens to the different positions without any prior communication of pattern information. Participants in the other two treatments played their games in two phases; in the first phase they used a tool (see

Figure 5) to communicate pattern information, and in the next phase they moved their tokens (like the BL). For the item level communication treatment, participants would select the unrevealed region and a dialog box like that in Figure 5 would pop-up. The dropdown box at the left would contain all possible numbers from all the patterns {1, 9, 10, 14, 19, 20} so that the team member could indicate what number they thought was in that region. They could also use the slider to indicate their confidence in their selection. These tools are examples of "lean"' communication mechanism as discussed by Kock (2001).

Place Figure 5 About Here

While the IC teams used the tool to indicate the values in specific regions, the participants in the chunk treatment used the very same tool with the pattern label set {9, 10, 14} in the dropdown box (thus tapping into the chunking concept). The IC and CC team members could see their colleagues pattern indications in real-time. Participants in the CC treatment were trained to chunk by associating a label for each of the three basic patterns; IC participants were not given pattern labels.

3.3 Dependent Measures

The dependent measures for the study are outcome quality and decision processes including pattern communication correctness, pattern communication time, and resource allocation time.

Outcome Quality is defined as the overall measure of team performance. It was assessed by computing the number of regions won by a team in a trial.

Pattern Communication Correctness is defined as the extent to which the patterns or items (for the IC treatment) communicated by team members are correct. For the IC treatment, we calculated the pattern-communicating correctness for each trial as the ratio of correctly identified values in critical regions to the total number of item level communication for those critical regions. A critical region is one whose value had to be ascertained to reveal the underlying pattern. The identification of these regions, which depended on the pattern type, was done by two of the researchers. For the CC treatment, pattern-communicating correctness was derived for each trial as a ratio of the number of team members who correctly identified the pattern to the total number of team members who communicated pattern information.

Pattern Communication Time is defined as the time taken by a team to communicate patterns or items (for the IC treatment). It was computed as the time taken by a team to exchange pattern information for a trial.

Resource Allocation Time is defined as the time taken by a team to play its resources. It was computed as the time taken by a team to play its tokens for a trial.

The following data were collected (with timestamps) to assess the above measures:

- within each trial, the pattern indicated to the team by each member as well as her level of confidence in the selection (from the pattern communication tool shown in Figure 5),
- within each trial, all player token movements, i.e. dragging a resource token from the "dock" to a region,
- after each trial, the sum of the team's resources allocated to each region,
- after each trial, the net score of regions won or lost, and
- team member demographics (age and gender).

3.4 Incentives

Subjects were externally motivated to take these experiments seriously and to behave "as if" they were making real allocation decisions (Cox, Roberson & Smith, 1982). This was accomplished by instituting a salient monetary payoff function directly related to the teams' outcome quality, as measured by the number of regions won in every trial:

Individual payoff per trial (US$) = (correct regions – 5) * $0.50

Subjects were informed of this function and told that money would be paid to each team member in cash at the end of the experiment. The incentive money was displayed to encourage them to believe they would indeed be paid. Subjects were also paid $5 to show up on time for the session. Individual participants typically earned $15-20 for the two-hour session.

4. DATA ANALYSIS AND RESULTS

There were 24, 19, and 13 teams in the BL, IC, and CC treatments respectively for a total of 171 subjects. The majority of the participants were male (73.7%). The average age was 23 years (ranging from 19 to 38 with the mode=21) with no significant differences across treatments. Subjects were paid a total of $2,486 for their participation and performance.

4.1 Outcomes

Analysis of Variance (ANOVA) and post-hoc Scheffé tests were conducted to test for differences in outcome quality among the three treatment groups. We chose the Scheffé test due to unequal sample sizes, and because in the general case, when many or all contrasts might be of interest, the Scheffé method tends to give narrower confidence limits and is recommended as the preferred method (Tukey, 1994).

Outcome quality was measured as the points (number of regions won) earned by each team per trial. The descriptive results are shown in Table 1. Outcome quality differs significantly among the treatment groups ($F=29.54$, $p<.000$). Specifically, the CC group out-performed the other two treatments, and the IC treatment had better scores than the BL treatment. Therefore, the results support Hypothesis 1, that the use of a pattern communicating tool improves outcome quality.

In addition to differences by treatment type, we found that the pattern type had a significant impact on outcome quality. As was expected, all teams performed better when confronted with definitive pattern types ($F=76.17$, $p<.000$).

4.2 Decision Processes

Our results on outcome quality lend support to our arguments for the use of pattern-communicating tools in collaborative decision-making. But, what impact does the use of the tool have on decision processes? To answer this question, we first compared the degree of pattern-communicating correctness between the IC and CC treatments. Results of ANOVA and post-hoc Scheffé tests (shown in Table 2) indicate that the CC group performed better than IC group (F=9.88, p<.002), supporting Hypothesis 2. Further, although the CC treatment's performance on pattern communicating correctness was superior to the IC group for both the equivocal and uncertain pattern types, the disparity is greater for the latter type (however, the interaction effect was not significant).

Analyses of pattern communication processes were conducted by examining the amount of time taken for exchanging pattern information (see Table 3). These results show that the CC treatment spent less time in pattern communication when compared to the IC treatment (F=370.06, p<.000), supporting Hypothesis 3.

Finally, as shown in Table 4, teams in the CC and IC treatments took significantly less time to move their tokens than BL treatment (F=86.92, p<.000). Thus, it appears that the pattern communication tool, whether used to share item or chunk information, had a significant impact on the time taken to complete the response selection and execution phases of our collaborative decision-making game. Furthermore, teams in the chunk communication treatment allocated their resources the quickest. These results show support for both Hypotheses 4a and 4b.

While our results show support for the premise that use of stimulating structures benefits team performance, it does not directly address whether the better performance is attributable to the tool improving the team's collaborative process or the cognitive ability of individual team members. Since our collaborative game measures performance at the team level, and not at the individual level, we addressed this issue indirectly. We computed a "good moves" index for each player based on her allocation of resources (tokens) to the different regions. For example, if a player moved a 6 or a 7 token to a 19 or 20 region, that move was categorized as a good move. We summed up all the good moves of a player and computed his good moves index by dividing this sum by the total number of moves made by the player.

Next, we conducted ANOVAs on the good moves index to test for differences across the three treatments. The results shown in Table 5 reveal two important insights: a) the communication tools did have an impact on individual cognitive ability (i.e., the item level communication and chunk level communication groups outperformed the baseline group), and b) improvements in the collaborative process must account for the difference in team performance between the item and chunk groups, since there is no significant difference between the two on improvements in individual cognition. Therefore, we can make a preliminary observation that the communication tools improve both individual cognition and team collaborative process.[2]

5. DISCUSSION

This research investigated pattern recognition and communication and outcome quality of teams engaged in a resource allocation task. In this section we discuss the findings and related implications from a theoretical and practical perspective.

5.1 Discussion of Findings

Klein's original model of individual Recognition Primed Decision-Making contends that response selection is contingent on situation assessment and pattern recognition. In a team environment where individuals have to collaborate to achieve high performance, the communication of individual situation assessment is crucial. Our results imply that by providing a stimulating structure, individual members were able to effectively communicate their assessment with each other, and therefore choose responses that collectively increased their team

[2] We would like to thank one of our anonymous reviewers for raising this issue. In future studies, we hope to more precisely isolate the contribution of individual cognition and group processes to overall team performance.

performance. Essentially, this stimulating structure created a public representation for memory and transformed situational awareness from an effortful memory task into a simpler perceptual task. The team member's limited cognitive resources were conserved (Wickens, 2002) so they could apply them to the resource allocation phase of the task. This might be reframed as saying teams compensated for the lean communication structure (Kock, 2001), which caused improved performance.

While both pattern communicating tools were associated with greater performance, the "chunk" level communication condition had significantly better outcomes. Chunks are a more efficient cognitive memory representation and a "chunk" label (Gobet and Simon, 1996a) created a quick pointer to LTM. The chunk tool facilitated cognitive alignment of memory retrieval structures; thus creating a good cognitive fit between the problem representation and memory (Vessey, 1991). This reduction in effort resulting from cognitive alignment left the team members with a greater proportion of cognitive resources available for the allocation task. Communicating this chunk label appeared to align the entire team (Doumont, 2002).

We believe that organizations can benefit by analyzing their group tasks; when groups face scenarios for which there are patterns, the patterns should be labeled and tools created to allow groups to communicate these labels with minimal task interruption to the sender and receiver. We expect that group members will create shared cognition through transactive memory and increase their performance (Canon-Bowers and Salas, 2001; Nosek and McNeese, 1997). Task specific knowledge is shared using the same construct, i.e. the chunk, which facilitates building shared cognition (in this case probably "overlapping", not identical). By having a shared awareness of who knows what information, cognitive load is reduced, and there is less redundancy of effort.

We do not feel that this result is limited to distributed teams. Co-located teams can also benefit from using a cognitively aligned tool for sharing pattern information. It should provide both a shorthand for the team to build shared cognition and be a focus point to keep them on task.

5.2 Implications for Practice

There are many team task domains that can benefit from tools that promote improved communication of pattern information. Specifically, distributed teams in collaborative decision making environments that are characterized by time pressure and/or limited capability to communicate information can benefit from the use of chunks represented by common labels. For example, individual investment analysts already use pattern-recognition-tools to improve the timely detection of buy and sell cues from the stock markets. We propose that if mutual fund management teams communicate to each other the prevailing market conditions (a recognized pattern) using "chunk" representations, e.g. the label "dead cat bounce", they may be able to better allocate their portfolio and increase fund performance. Similar opportunities to increase performance by communicating chunk information exist for project management teams in both the public and private sector, e.g. construction, software development, product design, bid review, or engineering teams that face detectable patterns.

In other domains, pattern-tool development is less mature: current air traffic control systems require a great deal of cognitive effort by their operators, and have the potential for significant improvements. For example, errors in baggage-screening could be reduced significantly through the application of pattern-communicating tools, and redesign of the task to facilitate group-based screening.

5.3 Future Research

In naturalistic environments, decision makers are faced with dynamic situations in which the patterns are constantly changing and they are faced with significant time pressure. In our study, the patterns were static for the duration of a trial. We are in the process of developing a version of our strategy game in which the patterns change during the course of a game trial and team members are faced with making their resource allocation decisions under time pressure. Once again, we believe that a pattern-communicating tool should reduce the cognitive loads on the team members, and promote improved performance because "chunks" can be retrieved with higher speed and accuracy.

A shortcoming to chunk theory has been the inability to explain how chess masters are able to play many concurrent games when blind-folded (Gobet & Simon, 1998), because this requires that experts acquire and search in a very short period of time, a vast database of chunks, containing, as a first estimate, 50,000 chunks. Recently, Gobet & Simon (2000) have shown that the time required to encode and retrieve these chunks is much shorter than previously thought. Furthermore, an expert can increase the size of their chunks based on new information; effectively increasing short-term memory (Gobet & Simon, 1998). To explain these findings, template theory has been proposed (Gobet & Simon, 1996b; 2000).

Templates have been referred to by various other names, i.e. schemas (Bartlett, 1932), frames (Minsky, 1977), prototypes (Goldin, 1978; Hartston & Wason, 1983), etc. Template theory assumes that many chunks develop into more complex structures (templates), having a "core" of data to represent the pattern, and slots for variable data to enhance the pattern core. In the domain of chess, templates allow rapid encoding and retrieval from LTM of more data than chunks (10-15 items as opposed to 4-5 items). For example, when a chess position pattern is recognized (say, as a King's Indian defense), the corresponding stored representation of the chess board provides specific information about the location of a number of pieces (perhaps a dozen) together with slots which may possess default values ("usual" placements in that opening) that may be quickly revised. Templates are cued by salient characteristics of the position. The core contains the constant information and the slots contain the variable information about the particular chess position. An interesting extension to our study would be to explore the applicability of template theory to visual-spatial pattern recognition tasks.

6. CONCLUSIONS

In our study we have demonstrated that a tool designed to support communication of patterns among group members was associated with significant improvements in performance in a collaborative game. In particular, communicating a "chunk" label associated with a pattern led to superior performance compared to communicating pieces of the pattern. Both pattern-communicating tools improved the collective recognition of patterns by our groups. We believe that the improvements in collective pattern recognition were a direct result of reducing the cognitive effort involved with perception and memory during the Situation Assessment phase of our model in Figure 2. This left more cognitive resources available to attend to the task at hand.

The normal concerns regarding the use of students as subjects could be viewed as a limitation of the study (external validity). However, we feel that basic cognitive processes apply across all populations. Another possible weakness of this study is that the experimental resource allocation task may be considered too simple. But, by using 3 patterns in 3 possible rotations with differing levels of revealed information, and no verbal communication, our pilot studies demonstrated that the task had enough complexity to be challenging within a two hour time block. Thus, the task required effortful cognition of the sort that is typical of many naturalistic domains. The groups in this study were ad-hoc, yet they were well-trained in the task and exhibited spirited, cohesive, collective identity as observed during payment and de-briefing.

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Figure 1: Model of the Human Information Processor (Card, Moran, and Newell, 1986)

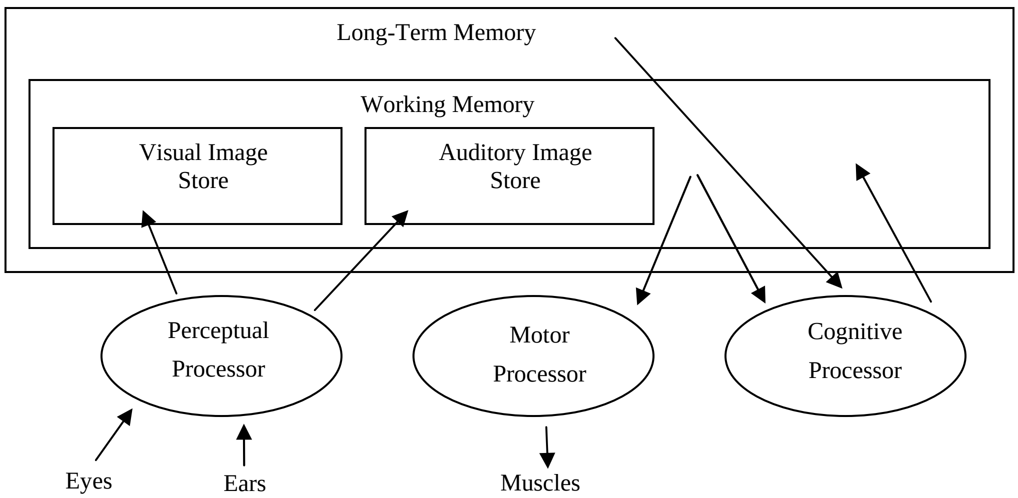


Figure 2: Team Recognition Primed Decision Making, adapted from Hayne, Smith, and Turk (2002).

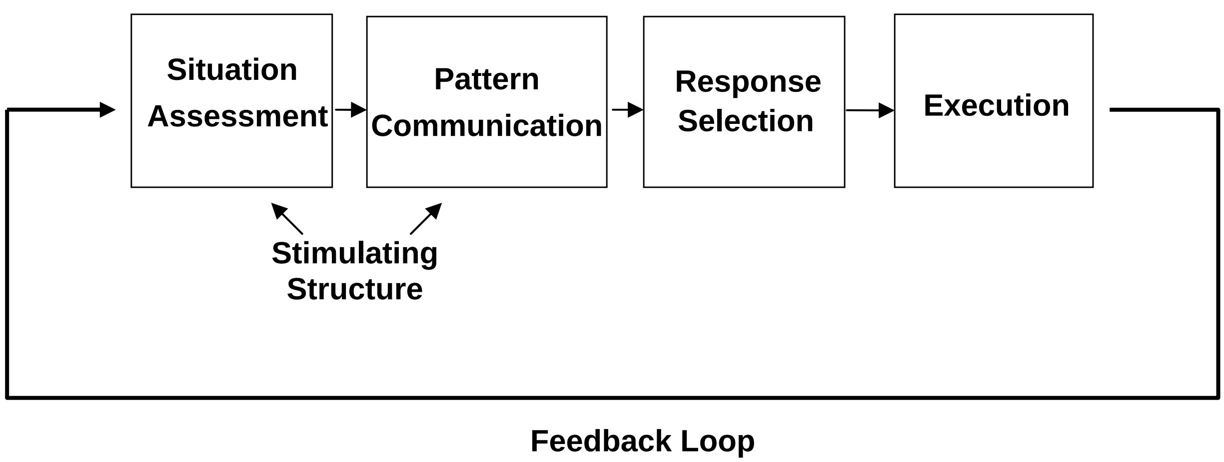


Figure 3: Multiplayer Collaborative Game

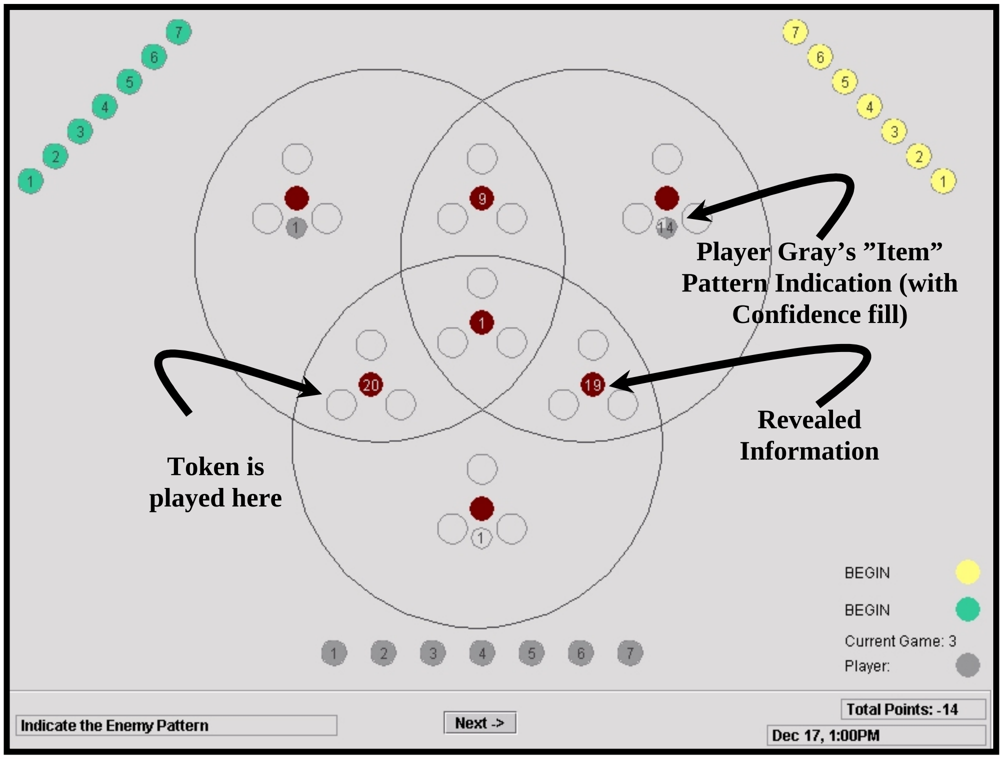
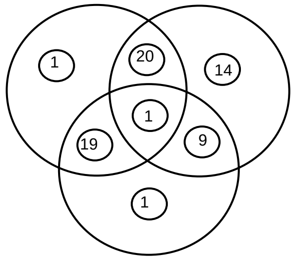
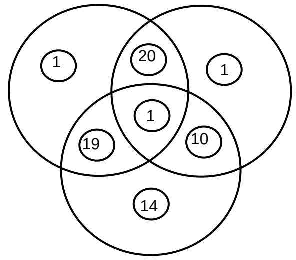


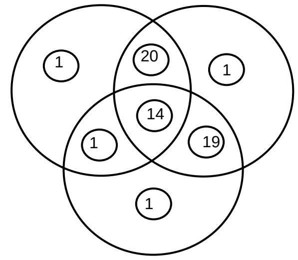
Figure 4: Game Patterns



Pattern 9



Pattern 10



Pattern 14

Figure 5: Pattern Communicating Tool

Table 1 – Outcome Quality

Descriptive Statistics

Treatment	Pattern Type									Total		
	Definitive			Uncertain			Equivocal					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Base Line	6.00	0.87	141	5.36	0.89	118	5.48	0.81	308	5.59	0.88	567
Items	6.26	0.79	119	5.64	0.85	99	5.66	0.87	256	5.81	0.88	474
Chunks	6.65	0.60	78	5.78	0.93	65	5.85	0.80	169	6.04	0.86	312
Total	6.24	0.82	338	5.55	0.90	282	5.63	0.84	733	5.77	0.89	1353

ANOVA Results

Source	df	Mean Square	F	Sig.
Treatment	2	20.35	29.54	.000
Pattern Type	2	52.46	76.17	.000
Treatment * Pattern Type	4	0.83	1.21	.305

Post-Hoc Scheffé Test Results for Treatment

Statistics	Pair-wise Comparisons		
	Chunks vs.		Items vs.
	Items	Base Line	Base Line
Mean Difference	0.23	0.45	0.22
Sig.	.000	.000	.000

Post-Hoc Scheffé Test Results for Pattern Type

Statistics	Pair-wise Comparisons		
	Definitive vs.		Uncertain vs.
	Uncertain	Equivocal	Equivocal
Mean Difference	0.69	0.61	-0.08
Sig.	.000	.000	.416

Table 2 – ANOVA Results for Communication Correctness

Descriptive Statistics

Treatment									
	Uncertain			**Equivocal**			**Total**		
	Mean	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
Items	0.23	0.35	82	0.29	0.39	220	0.28	0.38	302
Chunks	0.42	0.44	65	0.35	0.40	169	0.37	0.41	234
Total	0.32	0.40	147	0.32	0.39	389	0.32	0.40	536

ANOVA Results

Source	**df**	**Mean Square**	**F**	**Sig.**
Treatment	1	1.54	9.88	.002
Pattern Type	1	0.00	0.03	.860
Treatment * Pattern Type	1	0.41	2.60	.108

Table 3 – ANOVA and Scheffé Test Results for Pattern Communication Time

Descriptive Statistics

Treatment	Pattern Type									Total		
	Definitive			Uncertain			Equivocal					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Items	1.75	0.72	105	1.88	0.81	90	1.99	0.70	228	1.91	0.73	423
Chunks	1.00	0.00	78	1.02	0.12	65	1.01	0.08	169	1.01	0.08	312
Total	1.43	0.66	183	1.52	0.75	155	1.57	0.72	397	1.53	0.72	735

ANOVA Results

Source	df	Mean Square	F	Sig.
Treatment	1	114.31	370.06	.000
Pattern Type	2	0.93	3.01	.050
Treatment * Pattern Type	2	0.87	2.81	.061

Post-Hoc Scheffé Test Results for Pattern Type

Statistics	Pair-wise Comparisons		
	Definitive vs.		Uncertain vs.
	Uncertain	Equivocal	Equivocal
Mean Difference	-0.08	-0.14	-0.06
Sig.	.380	.019	.572

Table 4 – ANOVA and Scheffé Test Results for Token Move Time

Descriptive Statistics

Treatment	Pattern Type									Total		
	Definitive			Uncertain			Equivocal					
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
Base Line	2.82	1.42	141	2.83	1.54	119	2.88	1.39	308	2.86	1.43	568
Items	2.12	0.77	119	2.27	0.84	99	2.21	0.83	257	2.20	0.82	475
Chunks	1.59	0.69	78	1.75	0.71	65	1.94	0.95	169	1.81	0.86	312
Total	2.29	1.18	338	2.39	1.24	283	2.43	1.19	734	2.39	1.20	1355

ANOVA Results

Source	df	Mean Square	F	Sig.
Treatment	2	109.01	86.82	.000
Pattern Type	2	3.07	2.45	.087
Treatment * Pattern Type	4	1.06	0.84	.499

Post-Hoc Scheffé Test Results for Treatment

Statistics	Pair-wise Comparisons		
	Chunks vs.		Items vs.
	Items	Base Line	Base Line
Mean Difference	-0.39	-1.04	-0.66
Sig.	.000	.000	.000

Post-Hoc Scheffé Test Results for Pattern Type

Statistics	Pair-wise Comparisons		
	Definitive vs.		Uncertain vs.
	Uncertain	Equivocal	Equivocal
Mean Difference	-0.10	-0.14	-0.04
Sig.	.550	.162	.867

Table 5 – ANOVA and Scheffé Test Results for Good Moves Index

Descriptive Statistics

Treatment	Good Moves Index		
	Mean	**SD**	**N**
Base Line	0.25	0.09	72
Items	0.35	0.11	60
Chunks	0.34	0.12	39
Total	0.31	0.11	171

ANOVA Results

Source	df	Mean Square	F	Sig.
Treatment	2	0.18	16.11	.000

Post-Hoc Scheffé Test Results for Treatment

Statistics	Pair-wise Comparisons		
	Chunks vs.		**Items vs.**
	Items	**Base Line**	**Base Line**
Mean Difference	-0.01	0.08	0.10
Sig.	.868	.000	.000